Mergen SMPS Board v0.0.1

Design by Ekrem Turan Fırat

20240101

October 2024

Contents:

MERGEN

Attention: This project is open source and still under development. The project is always dangerous because it involves grid electricity's transformation and control. The engineer is not responsible for any adverse situation that may occur.

Contact: ig:mergenelk

1) Purpose and Definition

This circuit is a student project and was made for learning purposes. The aim is to learn power electronics. The information given now is a sign of respect for everyone who helped me learn this information. Knowledge increases as it is shared.

This circuit aims to adjust the 36VAC (Mains electricity will be converted to this level with a transformer) input in the range of 0-30VDC. The project, which is currently 150 Watt, is a starting step for a 500 Watt keypad controlled power supply in the future.

2) Circuits and Design Values

a. POWER

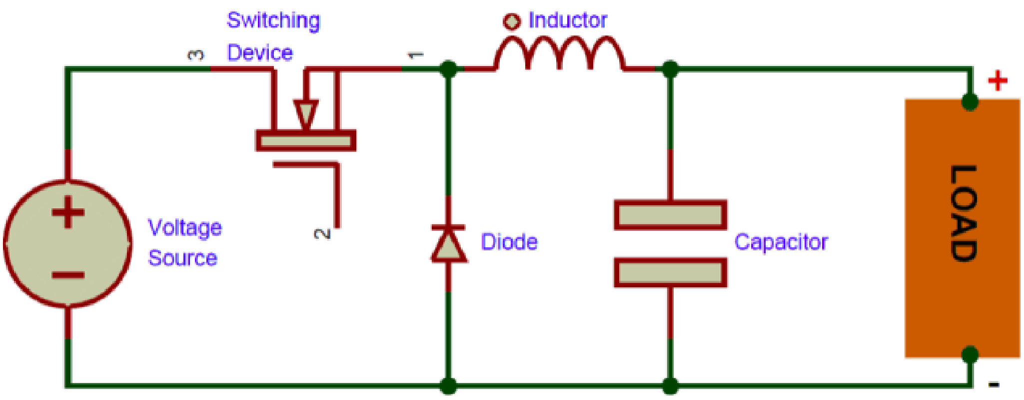
- The power input will be 36VAC, after DC conversion the output is 50.904... This output will be controlled as 30 Volts.
  - AC to DC conversion rates:
    - AC Effective Value → V_{rms}, $I_{rms} = V_{max}/\sqrt{2}$ or $V_{max}*0.707$
    - AC Peak Value → $V_{max} = V_{rms}*\sqrt{2}$ or $V_{rms}*1.404$
- Here, since our 36 Volt AC input will be converted to Vmax during DC conversion, the value of 36*1.404 is approximately 50.904, and 50 Volt output will be accepted for balance for losses and control purposes.

i. System Power Distribution

- The 50V input of the system will be divided into different voltage levels such as GATE Driver, Display and microcontroller etc.

  - Texas Instruments UCC27282 will be used for GATE Driver. Since the recommended input voltage of the integrated circuit is 5.5V - 16V, it is necessary to convert the 50V input to this range with a linear converter.
    - Conversion will be made with MAX5084 Linear Power Regulator Integrated Circuit
    - Set Pin Resistance Formula → R1=R2[Vout/Vset - 1]
    - R1 = 5K R2= 1K values Vout = 7.5V
  - 3.3V conversion will be made with AMS1117 derivatives for the microcontroller.

ii. SMPS Buck Converter Calculations and Values



The values you determine at this point depend entirely on your design requests and the results that arise from them. For example, since I wanted a maximum output of 30 volts for a 50V input, a Maximum Duty Cycle of 75% was created at 80% efficiency.

- Efficiency → 80% (Estimated)
- Maximum Input Voltage → 51V
- Minimum Input Voltage → 50V
- Output Voltage → 0-30V
- Output Current 5A max
- Frequency → 100000Hz = 100 kHz
- Maximum Duty Cycle → 75% = 0.75

- Inductor Ripple Current → ΔIL = 1.5A

  ΔIL = Iout*0*3 = 5A*0.3

- Coil Inductance Value → L = 80uh

  L = Vout*(Vin -Vout)/(ΔIL*f*Vin) = 30*(20)/(1.5*100000*50)

- Capacitor Value → C = 6.25 µF

  C = ΔIL/(8*f*Vout) = 1.5/(8*100000*30)

- Diode Current → ID = 1.25A

  If = Iout*(1-D) = 5*(0.25)

b. Microcontroller

There is a STM32C011F6U6TR microcontroller on the board for switching.

There are test points on the PCB to be able to code the board and control the pins from outside.

The microcontroller operates at a frequency of 3.3V and 48 mHz and produces the switching frequency, and also performs voltage/current readings with the microcontroller circuit ACS712 and voltage dividers.

Due to the lack of pins on the controller, the classic 16*2 LCD screen is used with I2C. Controls made via buttons are shown on the screen.

Current limiting is done by measuring the current digitally and controlling the line with a relay.

3) Schematics

Mergen Switch Mode Power Supply Board

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Project Purpose

This project aims to use 220VAC in 0-30V direct current with transformer and converter circuits.

Power Distribution

The scheme aims to filter 36VAC from an externally connected transformer and convert it into Direct Current to provide the necessary voltage to the components and the system.

MicroController

In this scheme, it is aimed to produce PWM, make the necessary measurements, reflect it on the screen and provide the output.

Gate Driver and MOSFETS

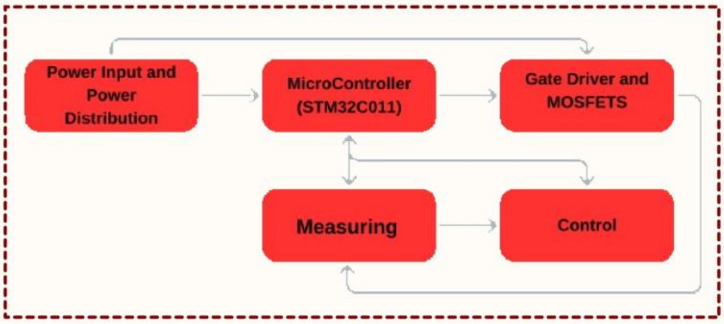
This scheme is intended to control the MOSFETs and filter the power output.

Measuring

This scheme is intended to measure the output current and voltage and ensure that the current limit is not exceeded.

Measuring

This diagram is intended to set the desired output voltage and current limit.



Port Colors

- **VAC Input**
- **Relay**
- **Control**
- **LCD**
- **Gates I/O**
- **Measuring**

Some port colors are left as default.

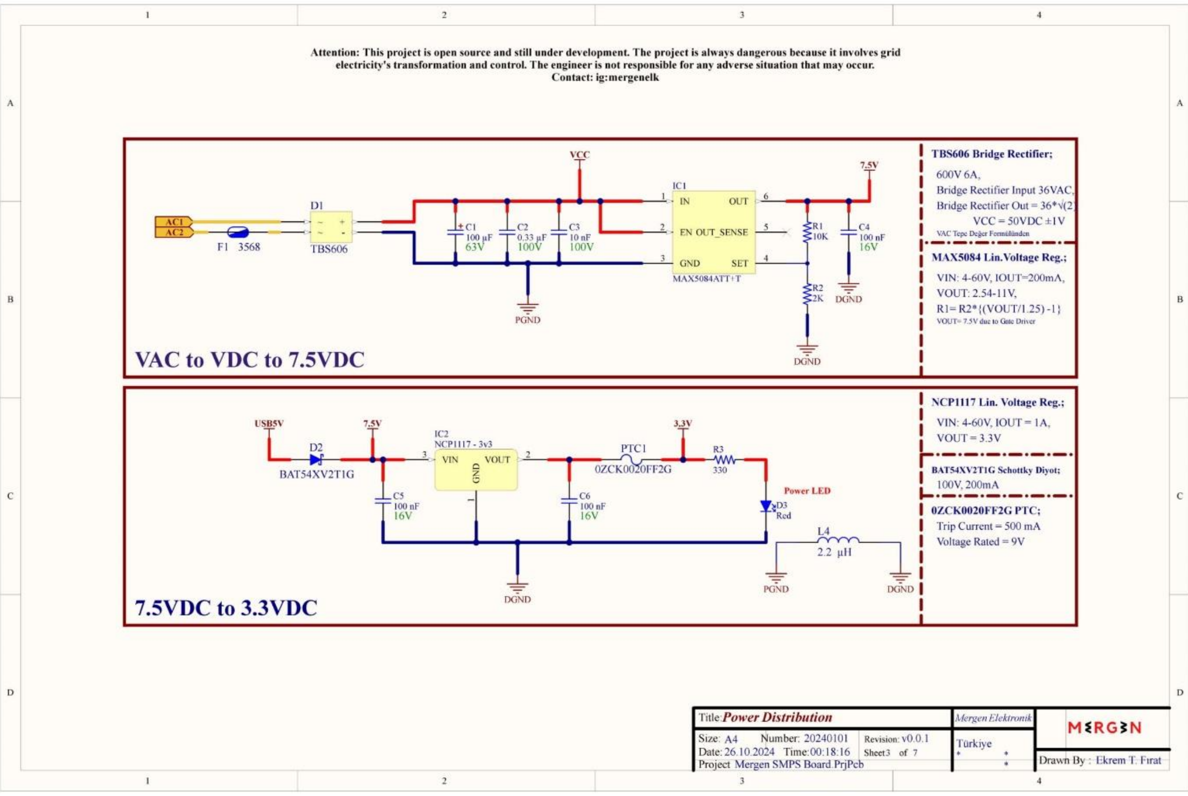
GND, VCC, 7.5V, 3.3V lines are specially used as thick and colored.

Resources

1) Basic Calculation of a Buck Converter's Power Stage, August 2015, SLVA447B - Texas Instruments
2) Understanding Buck Power Stages in Switchmodes Power Supplies, March 1999, SLVA057 - Texas Intruments
3) STM32C011 Datasheet, January 2024, STM32C011x4/x6 - STMicroelectronics
4) UCC27282 Datasheet, May 2022, UCC27282 - Texas Instruments
5) Best of Power Tips, SSZTCY0 - Texas Instruments
6) and component datasheets :)

Thank you to everyone who provided their information and opinions.

Title: *Description*	Mergen Elektronik	MERGEN
Size: A4 Number: 20240101 Revision: v0.0.1	Türkiye	
Date: 26.10.2024 Time: 00:18:16 Sheet2 of 7		Drawn By : Ekrem T. Fırat
Project: Mergen SMPS Board.PrjPcb		



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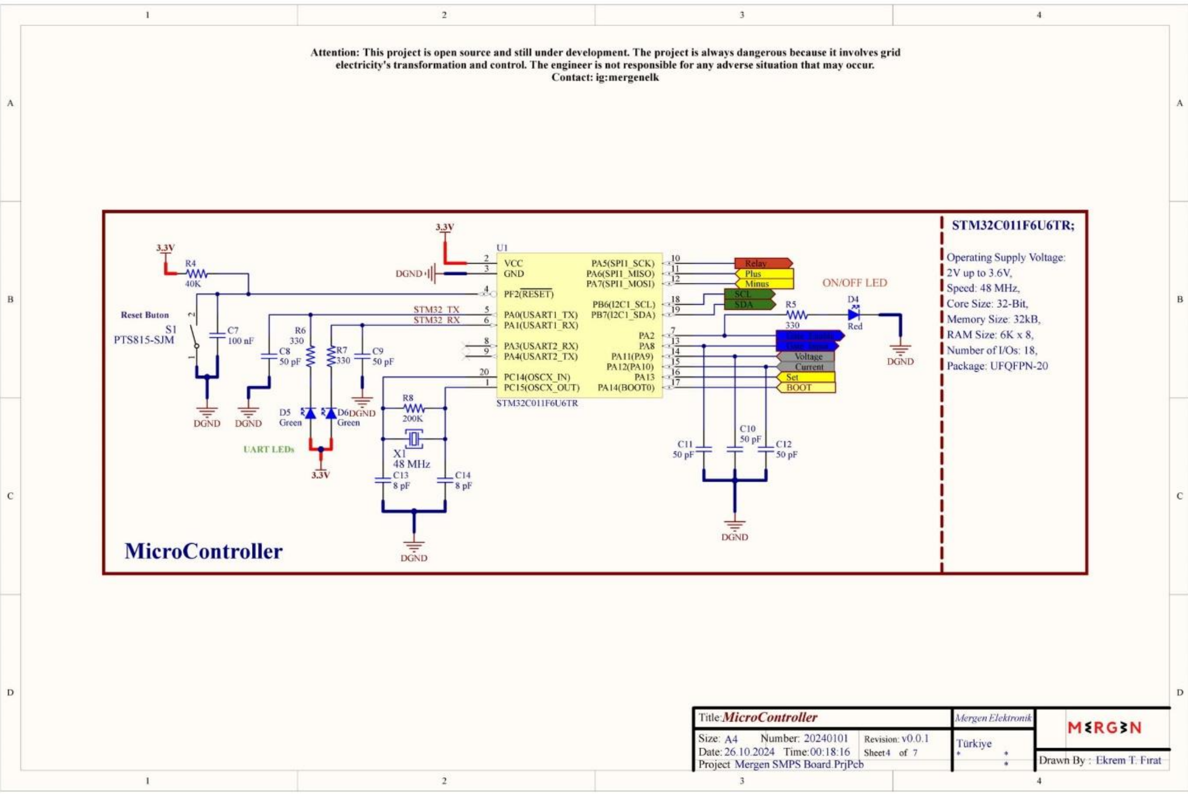
Contact: ig:mergenelk
VAC to VDC to 7.5VDC
AC1
AC2
F1 3568
D1
TBS606
VCC
C1 100 µF 63V
C2 0.33 µF 100V
C3 10 nF 100V
PGND
IC1
IN
EN OUT_SENSE
GND
OUT
SET
MAX5084ATT+T
7.5V
R1 10K
R2 2K
C4 100 nF 16V
DGND
TBS606 Bridge Rectifier;
600V 6A,
Bridge Rectifier Input 36VAC,
Bridge Rectifier Out = 36*√(2)
VCC = 50VDC ±1V
VAC Tepe Değer Formülünden
MAX5084 Lin.Voltage Reg.;
VIN: 4-60V, IOUT=200mA,
VOUT: 2.54-11V,
R1= R2*{(VOUT/1.25) -1}
VOUT= 7.5V due to Gate Driver
7.5VDC to 3.3VDC
USB5V
D2
BAT54XV2T1G
7.5V
IC2
NCP1117 - 3v3
VIN
VOUT
GND
C5 100 nF 16V
C6 100 nF 16V
3.3V
PTC1
0ZCK0020FF2G
R3 330
Power LED
D3 Red
L4 2.2 µH
PGND
DGND
NCP1117 Lin. Voltage Reg.;
VIN: 4-60V, IOUT = 1A,
VOUT = 3.3V
BAT54XV2T1G Schottky Diyot;
100V, 200mA
0ZCK0020FF2G PTC;
Trip Current = 500 mA
Voltage Rated = 9V
Title: Power Distribution
Size: A4 Number: 20240101 Revision: v0.0.1
Date: 26.10.2024 Time: 00:18:16 Sheet3 of 7
Project Mergen SMPS Board.PrjPcb
Mergen Elektronik
Türkiye
Drawn By : Ekrem T. Fırat



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Contact: ig:mergenelk
3.3V
R4 40K
Reset Buton
S1
PTS815-SJM
C7 100 nF
C8 50 pF
R6 330
R7 330
C9 50 pF
D5 Green
D6 Green
UART LEDs
DGND
U1
VCC
GND
PF2(RESET)
PA0(USART1_TX)
PA1(USART1_RX)
PA3(USART2_RX)
PA4(USART2_TX)
PC14(OSCX_IN)
PC15(OSCX_OUT)
STM32_TX
STM32_RX
PA5(SPI1_SCK)
PA6(SPI1_MISO)
PA7(SPI1_MOSI)
PB6(I2C1_SCL)
PB7(I2C1_SDA)
PA2
PA8
PA11(PA9)
PA12(PA10)
PA13
PA14(BOOT0)
STM32C011F6U6TR
Relay
Plus
Minus
SCL
SDA
Voltage
Current
Set
BOOT
ON/OFF LED
R5 330
D4 Red
R8 200K
X1 48 MHz
C13 8 pF
C14 8 pF
C11 50 pF
C10 50 pF
C12 50 pF
MicroController
STM32C011F6U6TR;
Operating Supply Voltage: 2V up to 3.6V,
Speed: 48 MHz,
Core Size: 32-Bit,
Memory Size: 32kB,
RAM Size: 6K x 8,
Number of I/Os: 18,
Package: UFQFPN-20
Title: MicroController
Size: A4 Number: 20240101 Revision: v0.0.1
Date: 26.10.2024 Time: 00:18:16 Sheet4 of 7
Project Mergen SMPS Board.PrjPcb
Mergen Elektronik
Türkiye
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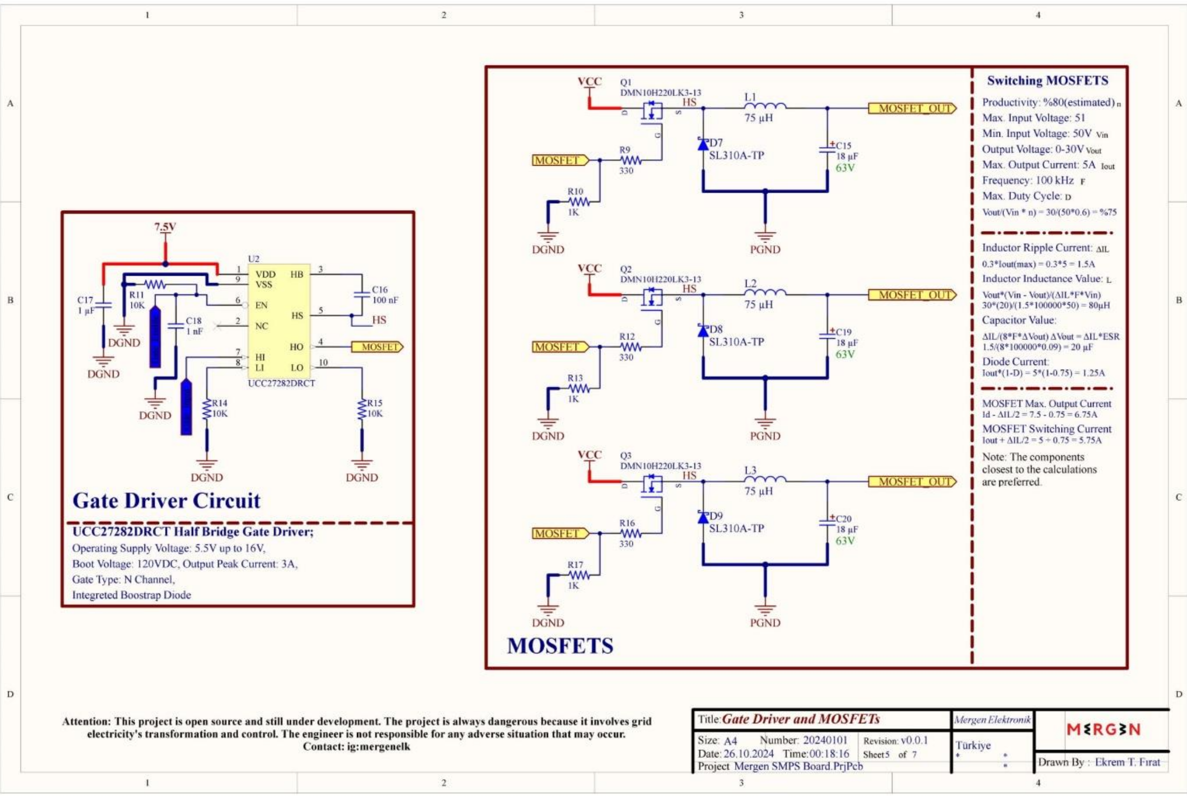
Gate Driver Circuit
UCC27282DRCT Half Bridge Gate Driver;
Operating Supply Voltage: 5.5V up to 16V,
Boot Voltage: 120VDC, Output Peak Current: 3A,
Gate Type: N Channel,
Integrated Boostrap Diode
7.5V
U2
VDD
VSS
EN
NC
HI
LI
HB
HS
HO
LO
UCC27282DRCT
C17 1 µF
R11 10K
C18 1 nF
C16 100 nF
R14 10K
R15 10K
DGND
MOSFET
MOSFETS
VCC
Q1 DMN10H220LK3-13
Q2 DMN10H220LK3-13
Q3 DMN10H220LK3-13
L1 75 µH
L2 75 µH
L3 75 µH
D7 SL310A-TP
D8 SL310A-TP
D9 SL310A-TP
C15 18 µF 63V
C19 18 µF 63V
C20 18 µF 63V
R9 330
R10 1K
R12 330
R13 1K
R16 330
R17 1K
MOSFET_OUT
PGND
Switching MOSFETS
Productivity: %80(estimated) n
Max. Input Voltage: 51
Min. Input Voltage: 50V Vin
Output Voltage: 0-30V Vout
Max. Output Current: 5A Iout
Frequency: 100 kHz F
Max. Duty Cycle: D
Vout/(Vin * n) = 30/(50*0.6) = %75
Inductor Ripple Current: ΔIL
0.3*Iout(max) = 0.3*5 = 1.5A
Inductor Inductance Value: L
Vout*(Vin - Vout)/(ΔIL*F*Vin)
30*(20)/(1.5*100000*50) = 80µH
Capacitor Value:
ΔIL/(8*F*ΔVout) ΔVout = ΔIL*ESR
1.5/(8*100000*0.09) = 20 µF
Diode Current:
Iout*(1-D) = 5*(1-0.75) = 1.25A
MOSFET Max. Output Current
Id - ΔIL/2 = 7.5 - 0.75 = 6.75A
MOSFET Switching Current
Iout + ΔIL/2 = 5 + 0.75 = 5.75A
Note: The components closest to the calculations are preferred.
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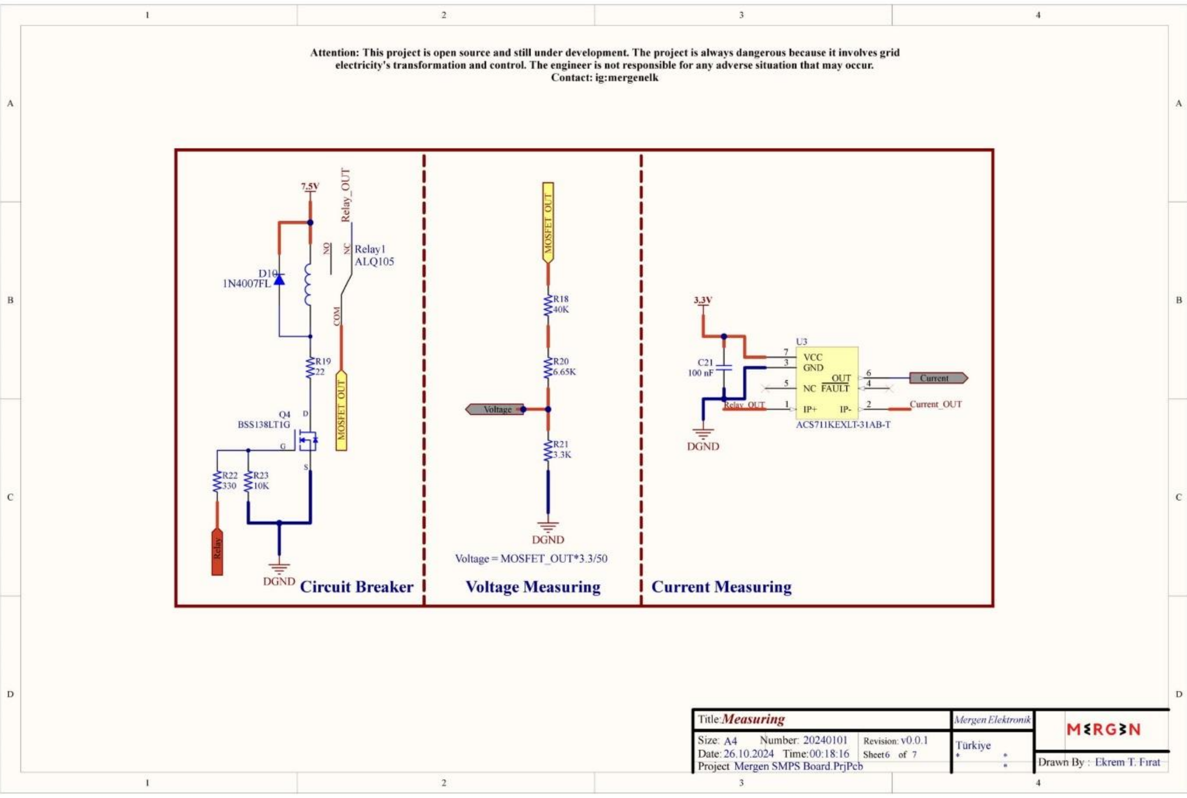
Contact: ig:mergenelk
Title: Gate Driver and MOSFETs
Mergen Elektronik
Size: A4 Number: 20240101 Revision: v0.0.1
Date: 26.10.2024 Time: 00:18:16 Sheet5 of 7
Project Mergen SMPS Board.PrjPcb
Türkiye
MERGEN
Drawn By : Ekrem T. Fırat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Contact: ig:mergenelk
7.5V
Relay_OUT
Relay1 ALQ105
D10 1N4007FL
R19 22
Q4 BSS138LT1G
R22 330
R23 10K
Relay
MOSFET_OUT
DGND
Circuit Breaker
R18 40K
R20 6.65K
R21 3.3K
Voltage
Voltage = MOSFET_OUT*3.3/50
Voltage Measuring
3.3V
C21 100 nF
U3
VCC
GND
NC
FAULT
OUT
IP+
IP-
ACS711KEXLT-31AB-T
Current
Current_OUT
Current Measuring
Title: Measuring
Mergen Elektronik
Size: A4 Number: 20240101 Revision: v0.0.1
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Project Mergen SMPS Board.PrjPcb
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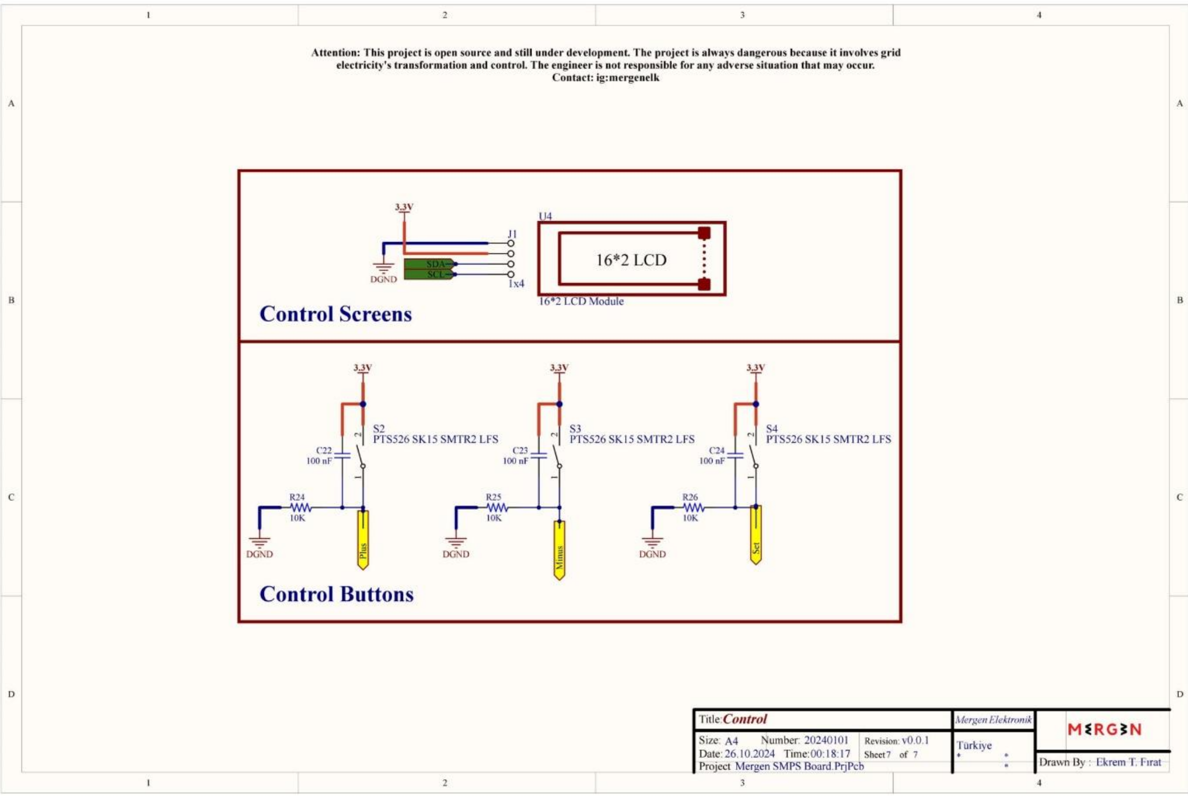
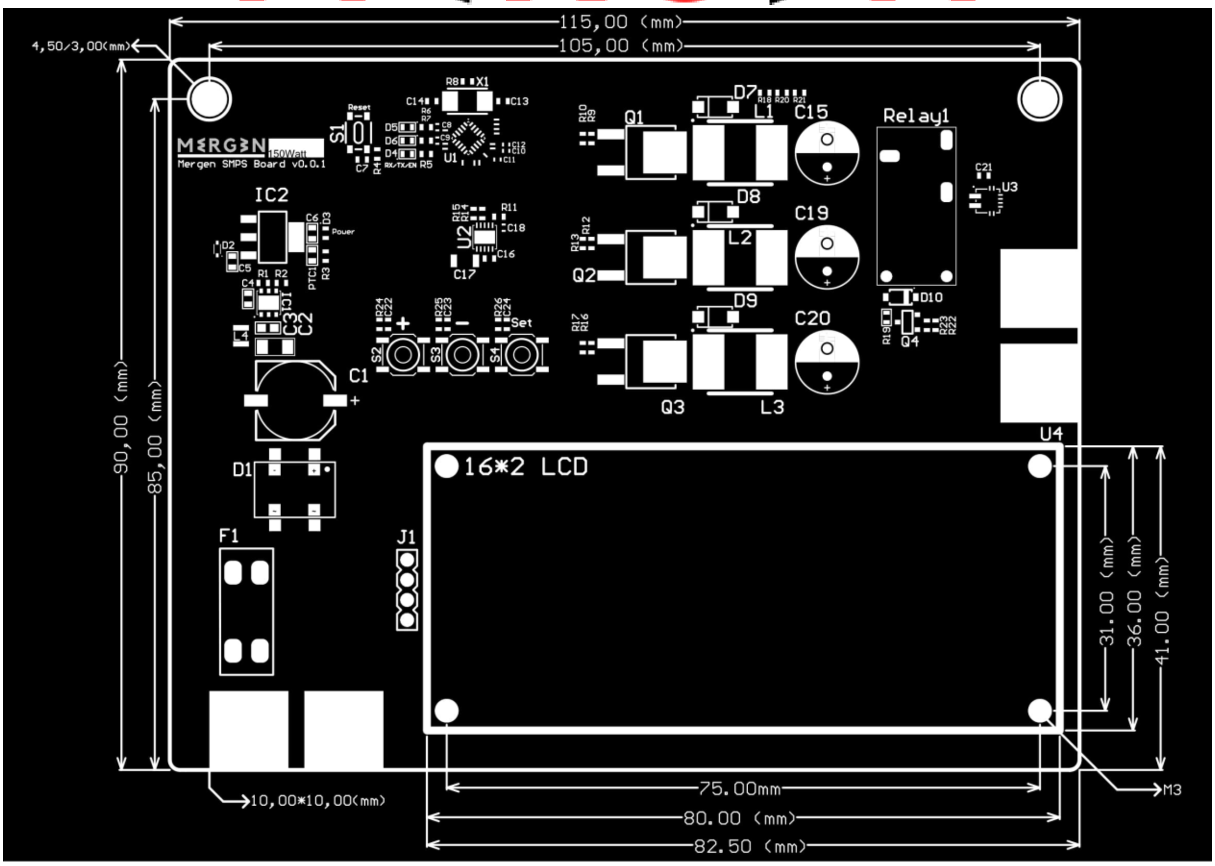
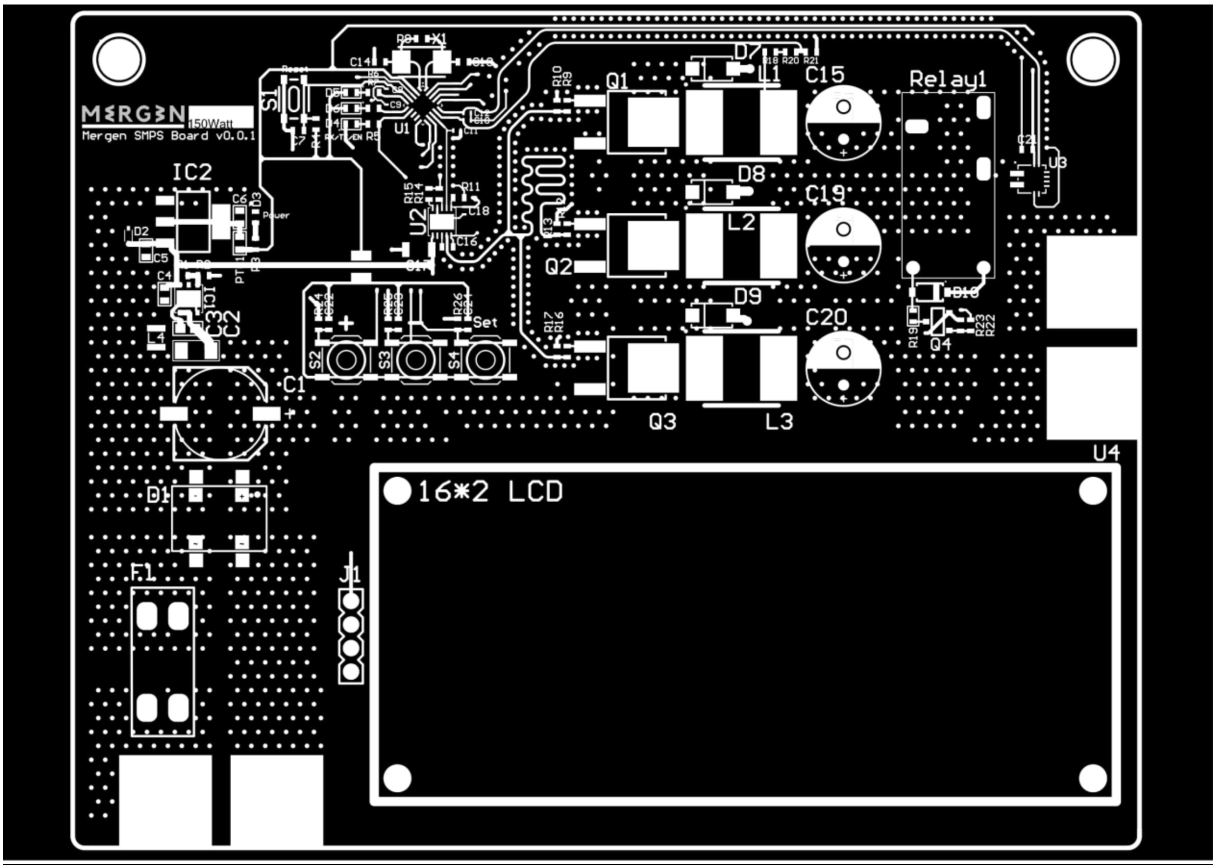
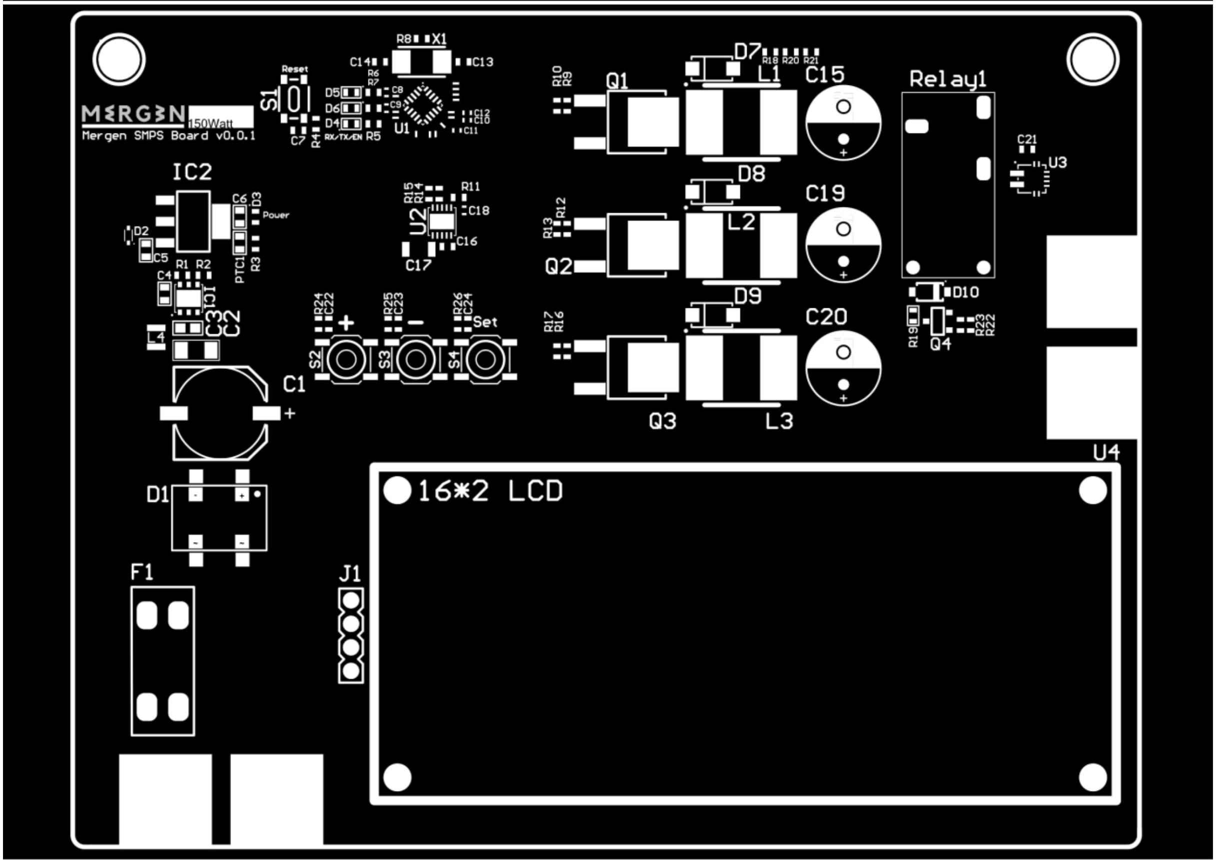
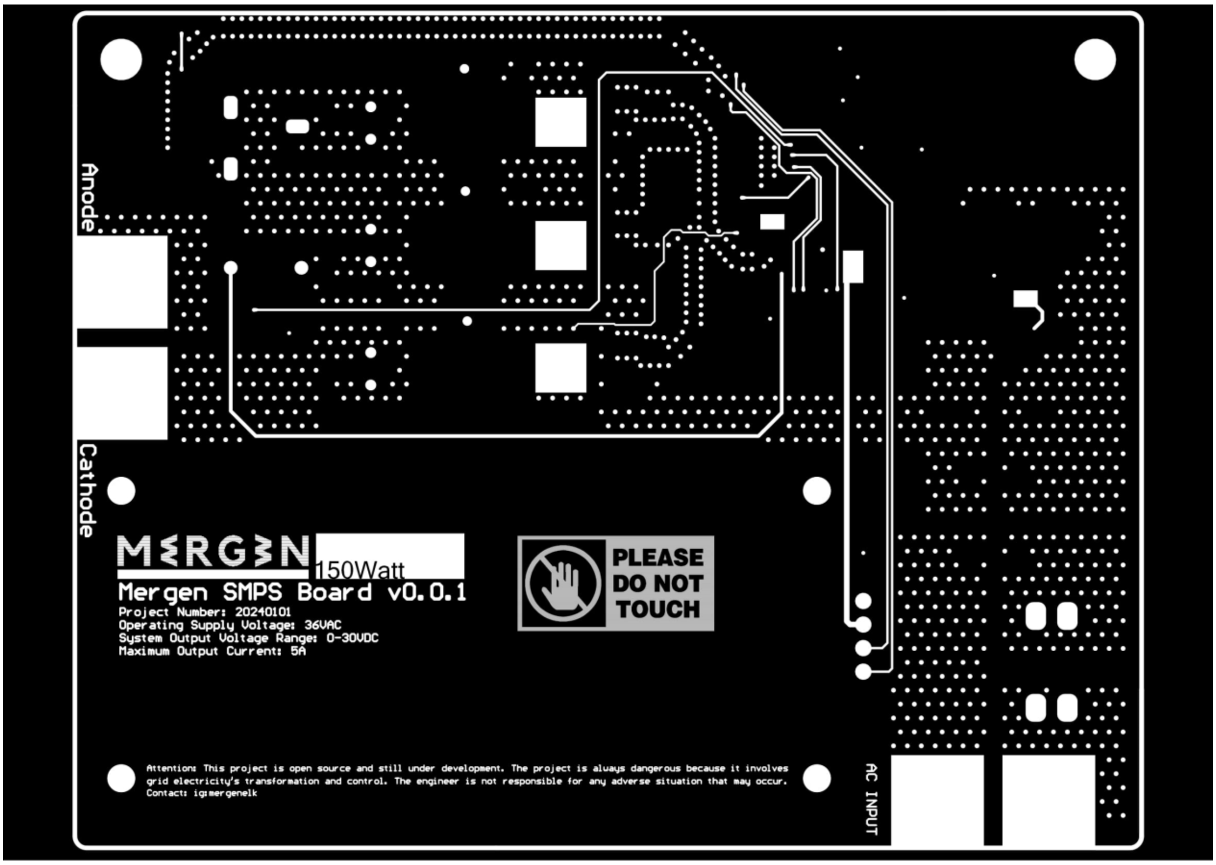


4) Printed Circuit Boards




MERGEN
150Watt
Mergen SMPS Board v0.0.1
IC2
Power
Reset
Relay1
Q1
Q2
Q3
L1
L2
L3
D7
D8
D9
D10
C15
C19
C20
C1
D1
F1
J1
U1
U2
U3
U4
Q4
S1
S2
S3
S4
+
Set
16*2 LCD


MERGEN
150Watt
Mergen SMPS Board v0.0.1
IC2
Power
Reset
Relay1
Q1
Q2
Q3
L1
L2
L3
D7
D8
D9
D10
C15
C19
C20
C1
D1
F1
J1
U1
U2
U3
U4
Q4
S1
S2
S3
S4
+
-
Set
16*2 LCD



Anode
Cathode
MERGEN
150Watt
Mergen SMPS Board v0.0.1
Project Number: 20240101
Operating Supply Voltage: 36VAC
System Output Voltage Range: 0-30VDC
Maximum Output Current: 5A
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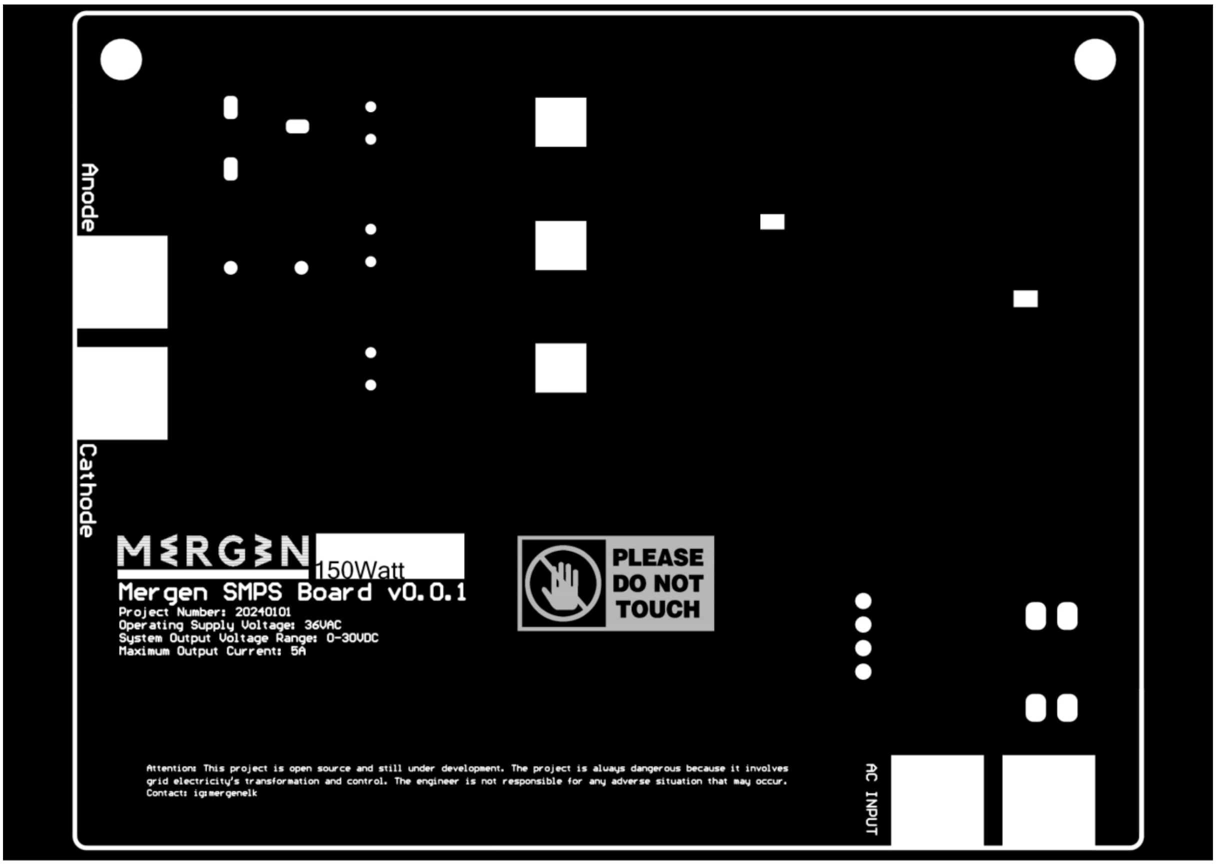
AC INPUT



Anode
Cathode
MERGEN
150Watt
Mergen SMPS Board v0.0.1
Project Number: 20240101
Operating Supply Voltage: 36VAC
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AC INPUT

5) Resources

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- STM32C011 Datasheet, January 2024, STM32C011x4/x6 - STMicroelectronics
- UCC27282 Datasheet, May 2022, UCC27282 - Texas Instruments
- Best of Power Tips, SSZTCY0 - Texas Instruments
- and component datasheets :)

- Thank you to everyone who provided their information and opinions.

Embedded software is under development.

Github.com/mergenelk

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